Home Work 4.

Due December 8

Problem 1 (30 points).

This question is about the adding-doubling method in the two-stream approximation. The azimuthally symmetric discrete-ordinate solar radiative transfer equation is obtained by using one quadrature angle μ_1 per hemisphere and two terms in the Legendre phase function series. For upwelling radiance I^+ the two-stream RTE is

$$\mu_1 \frac{dI^+}{d\tau} = I^+ - \frac{\omega}{2}\left[\left(1+3g\mu_1^2\right)I^+ + \left(1-3g\mu_1^2\right)I^-\right] - \frac{\omega}{4\pi}\left(1-3g\mu\ \mu_0\right)S_0 e^{-\tau/\mu_0}$$

where $I^{\pm} = I(\tau, \pm\mu_1)$ are the discrete ordinate radiances. For downwelling radiance I^- the two-stream RTE is

$$\mu_1 \frac{dI^-}{d\tau} = -I^- + \frac{\omega}{2}\left[\left(1-3g\mu_1^2\right)I^+ + \left(1+3g\mu_1^2\right)I^-\right] + \frac{\omega}{4\pi}\left(1+3g\mu\ \mu_0\right)S_0 e^{-\tau/\mu_0}$$

a) *Calculate the reflection R, transmission T and source $S^{\pm}$ coefficients for and infinitesimally thin layer of optical depth $\delta\tau$. Note: for a homogeneous layer $R^+=R^-$ and $T^+=T^-$.*
b) *If we do the standard direct/diffuse solar radiation separation, what are the boundary conditions (i.e. incident radiances) on the layer in the interaction principle? Hence, what are the terms in the interaction principle gives the radiance outgoing from the atmosphere?*
c) *Use the doubling relation to compute the albedo as function of optical depth for $\omega=1.0$ and $\omega=0.99$. Use a solar zenith angle of 30 ° ($\mu_0=0.866$), asymmetry parameter g=0.85, and a black surface. The double gaussian quadrature angle is $\mu_1=1/2$ with weight w=1. Use delta scaling with $f=g^2$. Start with $\delta\tau=1/1024$ and double to $\tau=64$. Convert the discrete ordinate radiance to albedo and plot the albedo curves. Hand in the program you've used to do computations.*

Problem *2* (30 points).

Compute the length of the day and daily near the top-of-atmosphere solar insolation (W/m2) at 65-degrees N on about July 21 for this year and 130,000 years ago. From Figure 2.7 in Liou (2002) the eccentricity then was about 0.038, the longitude of the perihelion from the vernal equinox was about 45°, and the obliquity was 24.0°. Assume that the longitude of the earth and the true anomaly are linearly proportional to time. What is the *relative size of the change in solar flux due to obliquity versus due to the sun-earth distance?*

Problem 3 (30 points)

a) *Calculate the radiative forcing for a solar constant increase of 0.1 % at sunspot maximum. Compare this with the current radiative forcing from the anthropogenic increase in trace gases.*

b) *Derive the climate sensitivity parameter G_0 for surface temperature with no climate feedback using a current surface temperature of 288 °K. It is easiest to assume that the outgoing long-wave flux is proportional to the emitted surface flux, $F_{LW}=(1-g)\sigma T_s^4$, where g is a normalized greenhouse factor. Why is g constant for no climate feedback?*

c) *What is the resulting no-feedback global surface temperature change for the current radiative forcing with anthropogenic gases?*

Problem 4. (30 points)

a) *Suppose cloud cover of all types decrease by 5 % (i.e. 0.03 for a cloud amount of 0.60) for each degree of surface temperature increase (and all other cloud properties stay constant). What is the feedback factor f_{cc} for this hypothetical cloud feedback? The cloud total (shortwave + longwave) radiative forcing results from ERBE are –17 W/m^2 for the global mean net effects of clouds. Is this a positive or negative feedback?*

b) *Climate models show that the water vapor feedback by itself increases the no-feedback climate sensitivity by a factor of 1.6 (i.e. $G_{\omega\upsilon}=1.6G_0$). What is the total climate sensitivity including the water vapor feedback and the cloud feedback in part a)?*

c) *It is unlikely that the change in cloud cover for all cloud types would be the same. Discuss how the cloud cover of 1) low altitude stratus clouds over the ocean and 2) thin high altitude cirrus clouds over land would cause radiative effects of opposite signs.*

Problem 5 (30 points).

a) *Assume that the atmosphere acts as a single isothermal layer with a temperature T_a that transmits solar radiation but absorbs all thermal infrared radiation. Show that the global surface temperature $T=(2)^{1/4}T_a$. Let the global albedo be 30 %, and the solar constant be 1366 W/m^2. What is the global surface temperature?*

b) *The mean global surface temperature is only about 15 °C. The mean global absorptivity of solar radiation by atmosphere is about 0.2. Use the* *global albedo and solar constant given in a) and compute the mean global emissivity and temperature of the atmosphere. Repeat the calculation if the solar constant decreases by 1 %.*